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(54) **SYSTEMS AND METHODS FOR TIME-MULTIPLEXING TEMPORAL PIXEL-LOCATION DATA AND REGULAR IMAGE PROJECTION FOR INTERACTIVE PROJECTION**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

6,301,044 B1 \* 10/2001 Huber ..... G02B 27/26  
348/E13.037  
6,345,116 B1 \* 2/2002 Kojima ..... H04N 1/3876  
358/518

7,933,809 B2 \* 4/2011 Abraham ..... G06Q 30/02  
705/26.1  
8,018,579 B1 \* 9/2011 Krah ..... G01B 11/00  
356/4.01  
8,217,997 B2 \* 7/2012 Solomon ..... G06F 3/0321  
348/63  
8,878,858 B2 \* 11/2014 Posa ..... G09G 3/001  
345/501  
9,153,175 B2 \* 10/2015 Song ..... G09G 3/3258

(Continued)

#### OTHER PUBLICATIONS

Johnny Lee et al. Hybrid infrared and visible light projection for location tracking. Proc. of the 20th ann. symp. on User Interf. (UIST '07). ACM New York, NY, USA, 57-60.

(Continued)

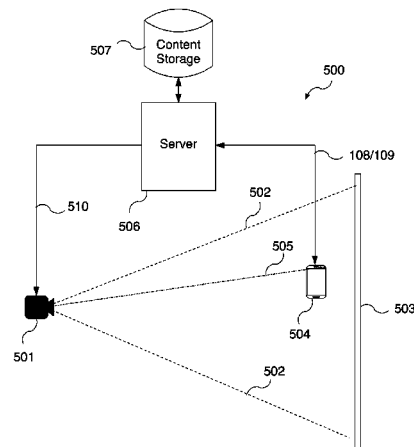
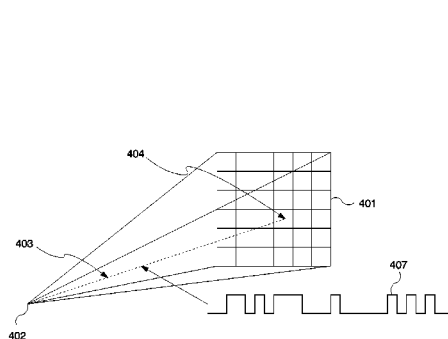
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(57) **ABSTRACT**

A system and method for generating a projected image signal encoded with position information. The temporal pixel-location data is hidden within visible light signal used for regular image projection. This enables the user to utilize one or multiple ring-shaped light receivers to implement touch or multi-touch functions on a regular image content generated using light from the same projector. The temporal light signal generated by the projector is sliced into multiple temporal segments. The segments include segments of two different types. A segment of the first type is used for carrying a temporal position signal of each pixel in the projector signal. On the other hand, a segment of the second type is used to adjust the color of each pixel. With the color adjustment segment projected to each image pixel, a meaningful visible content of a regular image can be displayed despite the presence of the position-encoded signal segments.

19 Claims, 6 Drawing Sheets



(56)

**References Cited****U.S. PATENT DOCUMENTS**

2002/0064306 A1\* 5/2002 Pilz ..... H04N 1/64  
382/166  
2002/0122042 A1\* 9/2002 Bates ..... G06F 17/30855  
345/581  
2003/0095138 A1\* 5/2003 Kim ..... H04N 9/73  
345/690  
2004/0222987 A1\* 11/2004 Chang ..... G01B 11/2509  
345/419  
2006/0215907 A1\* 9/2006 Shefer ..... H04N 1/646  
382/166  
2006/0269136 A1\* 11/2006 Squires ..... G06K 7/1443  
382/181  
2007/0005795 A1\* 1/2007 Gonzalez ..... G06F 17/30017  
709/232  
2007/0046924 A1\* 3/2007 Chang ..... G01C 7/00  
356/3.01  
2007/0091434 A1\* 4/2007 Garner ..... H04N 5/74  
359/459  
2007/0206204 A1\* 9/2007 Jia ..... G01N 11/254  
356/604  
2007/0247519 A1\* 10/2007 Riazat ..... G09F 19/12  
348/37  
2008/0025631 A1\* 1/2008 Neal ..... G06K 9/00456  
382/260  
2008/0158268 A1\* 7/2008 Hui ..... G09G 3/2022  
345/691  
2009/0184976 A1\* 7/2009 Chen ..... G09G 3/2003  
345/604  
2010/0316389 A1\* 12/2010 Walewski ..... H04B 10/1141  
398/130  
2011/0055729 A1\* 3/2011 Mason ..... G06F 3/0425  
715/753  
2011/0164191 A1\* 7/2011 Brown ..... G06K 9/50  
348/744  
2011/0181553 A1\* 7/2011 Brown ..... G06F 3/0425  
345/175

2011/0292299 A1\* 12/2011 Lau et al. .... 348/734  
2012/0038892 A1\* 2/2012 Kurtz et al. .... 353/31  
2012/0307897 A1\* 12/2012 Yang ..... H04N 19/50  
375/240.12  
2013/0076763 A1\* 3/2013 Messmer ..... H04N 1/6058  
345/506  
2013/0187954 A1\* 7/2013 Saito ..... G02B 21/365  
345/634  
2013/0215132 A1\* 8/2013 Fong ..... G06F 3/011  
345/582  
2014/0022169 A1\* 1/2014 Stern ..... G06F 3/033  
345/157  
2014/0022196 A1\* 1/2014 Henry ..... G06K 9/3258  
345/173  
2014/0043352 A1\* 2/2014 Damberg ..... H04N 9/3147  
345/589  
2014/0071116 A1\* 3/2014 Johansson ..... G06T 19/006  
345/419  
2015/0212595 A1\* 7/2015 Liu ..... G06F 3/0321  
345/156  
2015/0221280 A1\* 8/2015 Van Der Vleuten . H04N 1/6027  
382/167  
2015/0245103 A1\* 8/2015 Conte ..... H04N 21/47815  
725/60  
2015/0262410 A1\* 9/2015 Arun ..... G06F 9/4881  
345/419  
2015/0281507 A1\* 10/2015 Konen ..... G06K 9/00664  
348/231.6  
2015/0281702 A1\* 10/2015 Chang ..... H04N 19/186  
382/166

**OTHER PUBLICATIONS**

Johnny C. Lee et al. Moveable interactive projected displays using projector based tracking. Proc. of 18th ann. symp. on User Interf. (UIST '05). ACM, New York, NY, USA, 63-72.

\* cited by examiner

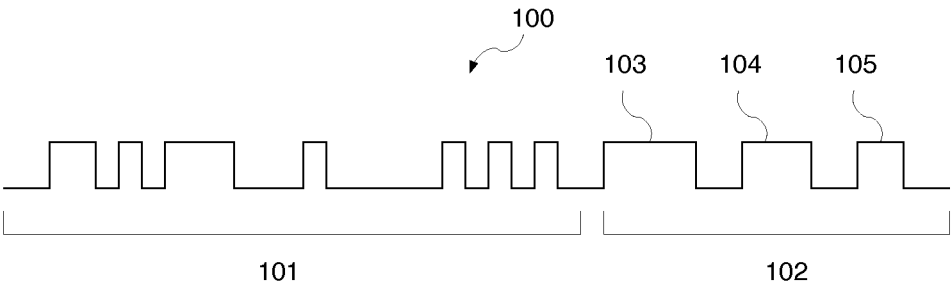


Figure 1

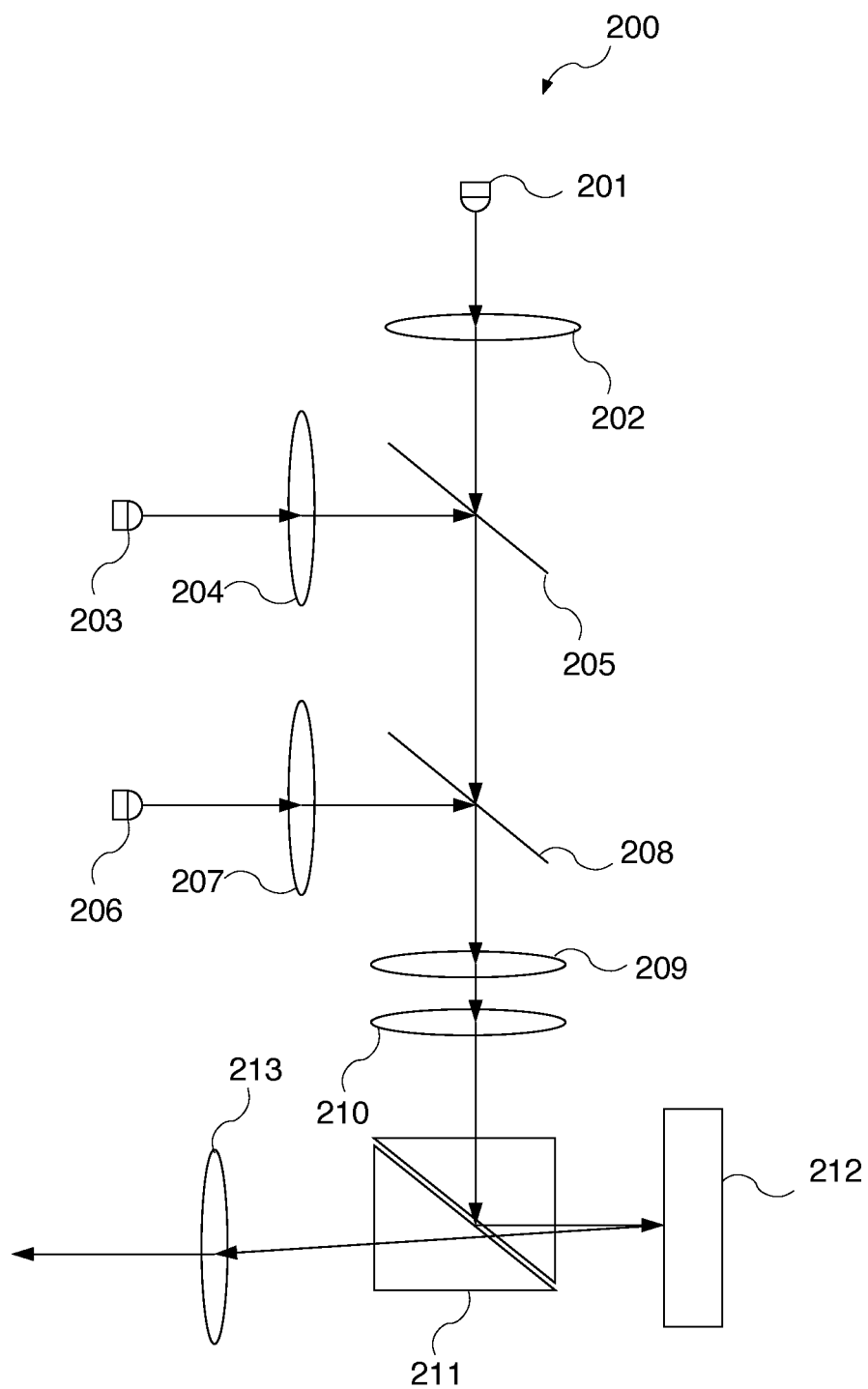


Figure 2

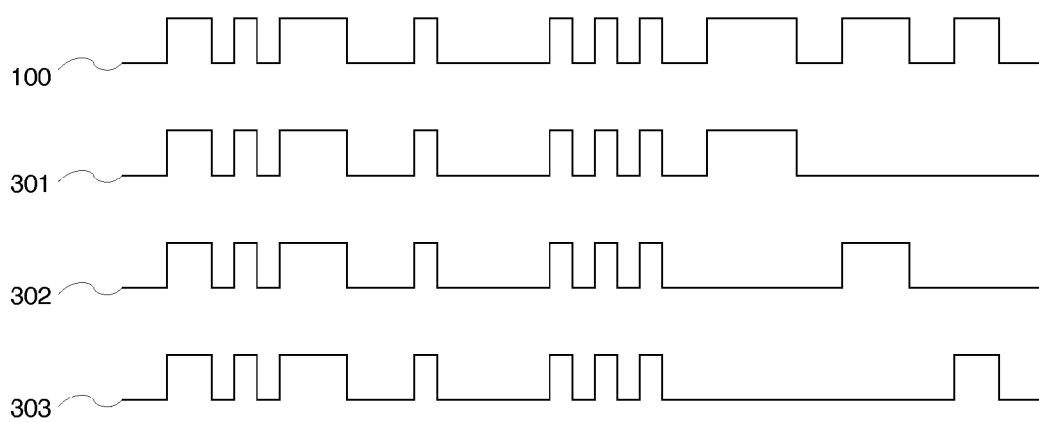


Figure 3

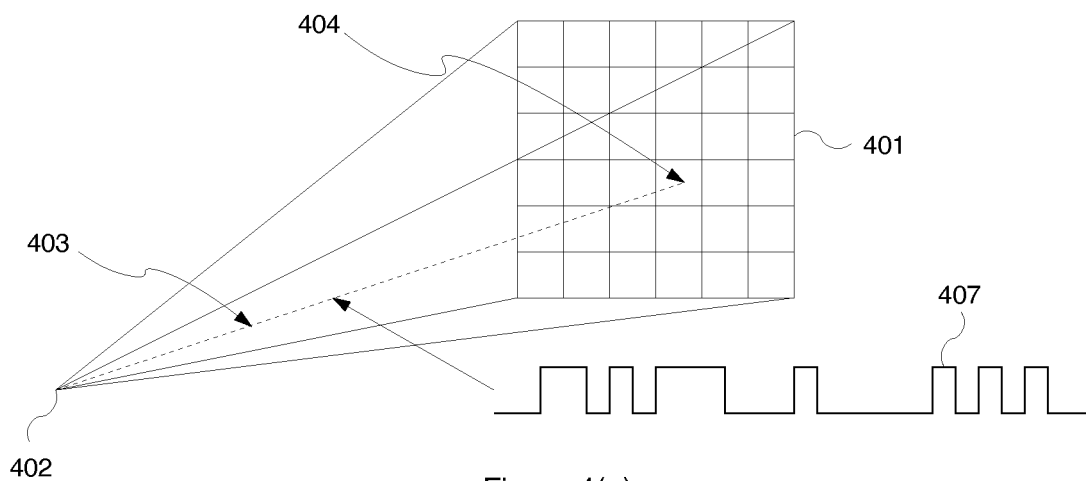


Figure 4(a)

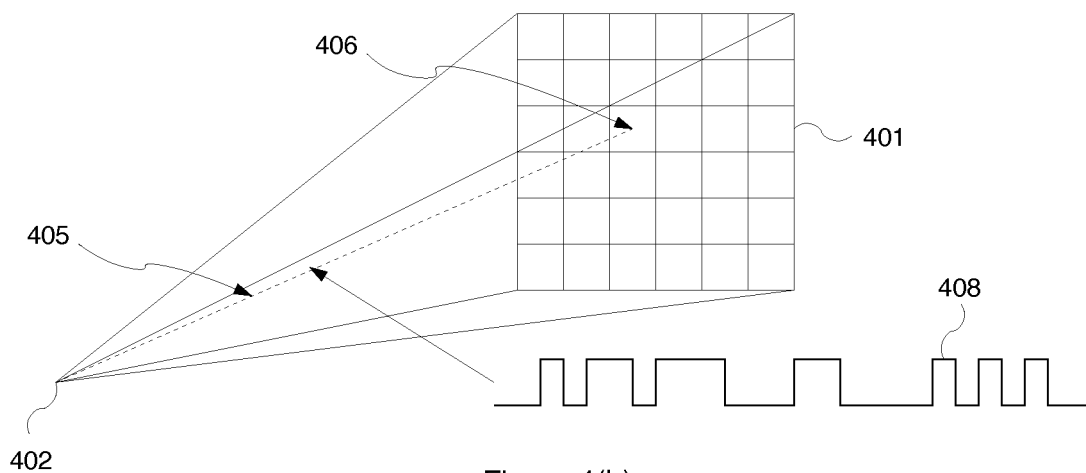


Figure 4(b)

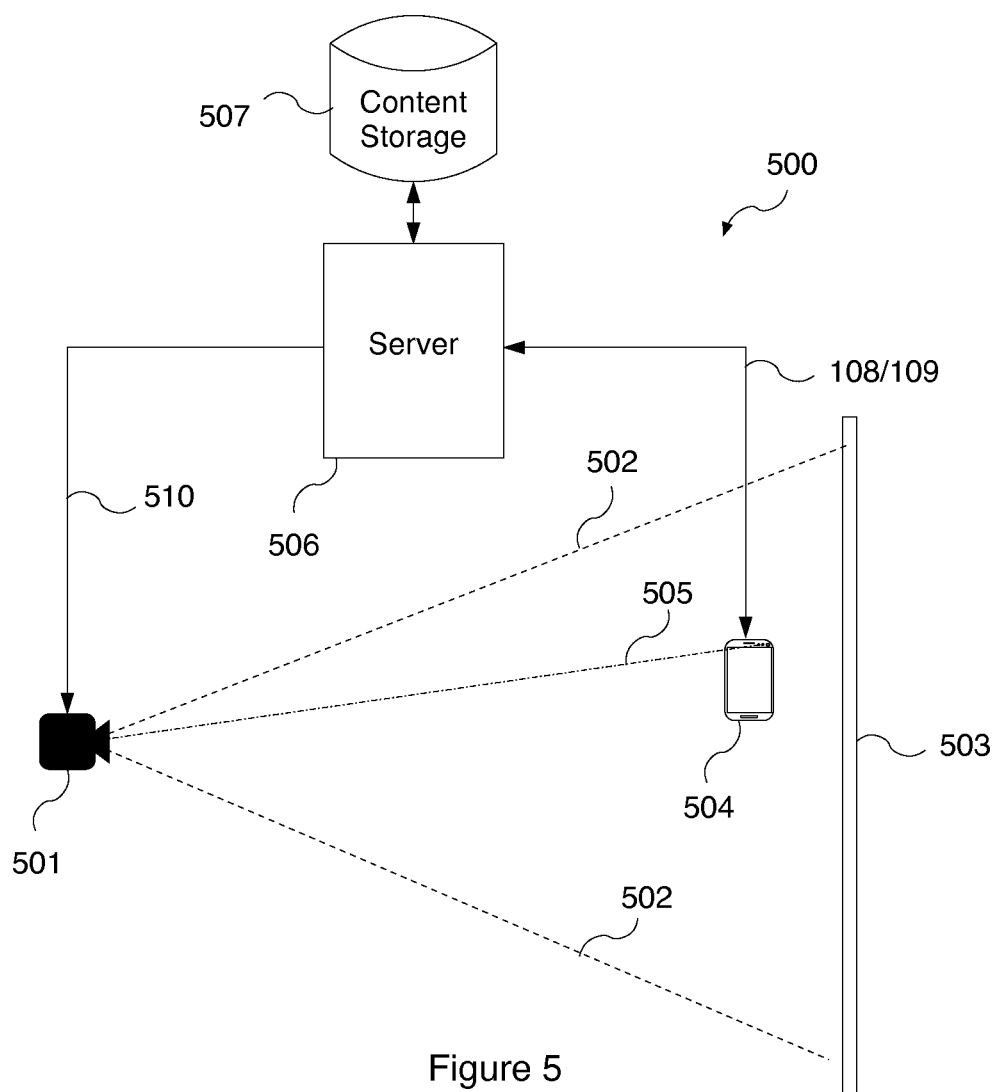


Figure 5

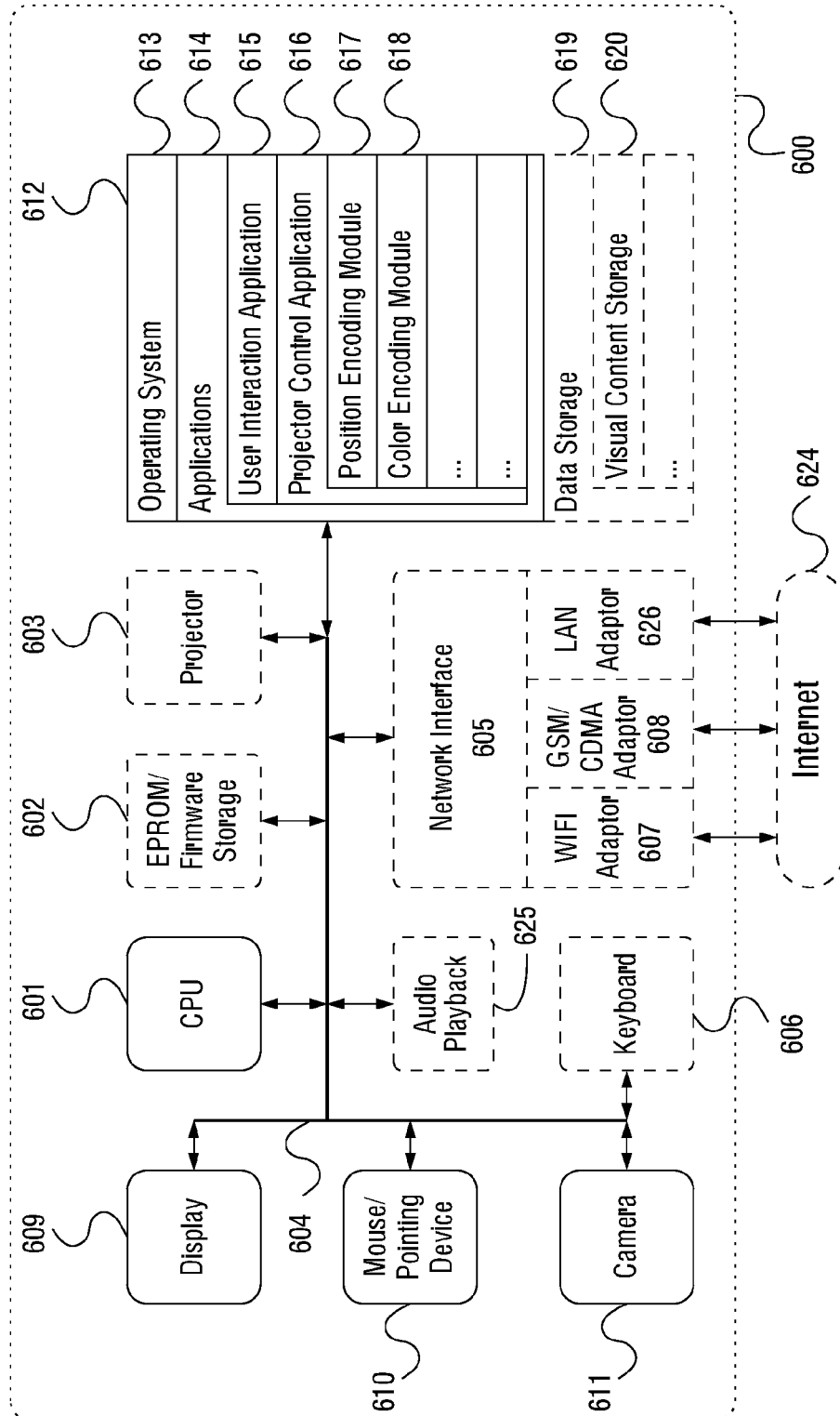


Figure 6



# SYSTEMS AND METHODS FOR TIME-MULTIPLEXING TEMPORAL PIXEL-LOCATION DATA AND REGULAR IMAGE PROJECTION FOR INTERACTIVE PROJECTION

## BACKGROUND OF THE INVENTION

### 1. Technical Field

The disclosed embodiments relate in general to systems and methods for user-computer system interaction and, more specifically, to systems and methods for time-multiplexing temporal pixel-location data and regular image projection for interactive projection.

### 2. Description of the Related Art

Many applications of user-computer interaction systems require tracking of a location of an object, such as user's smartphone. For example, a user may place his smartphone next to an item in a museum or a store in order to receive additional information about that item. The system tracks the location of the user's smartphone and uses the determined location to identify the item of interest to the user in order to retrieve and provide to the user the additional information about the item. A similar system may be used to enable user's interaction with a projected public display, wherein a user interface is projected on a surface. The user interacts with such a display by performing gestures using his or her smartphone.

In the above-referenced user-computer interaction systems, the location of the user's smartphone is determined using coded lighting generated by a projector. As would be appreciated by persons of ordinary skill in the art, to enable such a system to function properly, the projector must be registered with the real-life objects, monitoring camera, or other tracking systems.

For projected augmented reality and augmented worktables, researchers explored many different approaches to register projector with real world objects, monitoring camera, or other tracking systems. As would be appreciated by persons of ordinary skill in the art, to perfectly align the regular image projection system and the tracking system, it is advantageous to have the signal for position-tracking and regular image go through the same light engine. This approach can greatly reduce problems encountered during real system deployment.

For example, Lee et al. proposed unifying tracking and projection by introducing an infrared (IR) channel beyond visible channel in his projection system, see Johnny Lee, Scott Hudson, and Paul Dietz, "Hybrid infrared and visible light projection for location tracking", In Proceedings of the 20th annual ACM symposium on User interface software and technology (UIST '07), ACM, New York, N.Y., USA, 57-60. However, this system requires a modification of the projector's light engine, which is expensive to perform in many commercially available projector systems. Moreover, the extra IR channel needs to be perfectly aligned with visible channels during light engine manufacturing process. As would be appreciated by persons of ordinary skill in the art, all these light engine physical changes will result in a significant cost increase of the light engine manufacturing.

Thus, new and improved systems and methods are needed that would provide a position-encoded image signal using a projector having the image generating light signal aligned with the light signal carrying the position information.

## SUMMARY OF THE INVENTION

The embodiments described herein are directed to systems and methods that substantially obviate one or more of

the above and other problems associated with the conventional technology for providing position-encoded light signal.

In accordance with one aspect of the embodiments described herein, there is provided a computer-implemented method performed in connection with a computerized system comprising a processing unit, a memory and a projector, the computer-implemented method involving: receiving an image data, the image data comprising at least a color value for each of a plurality of pixels of an image, the color value representing a color of said each of the plurality of image pixels, wherein each of the plurality of image pixels is characterized by pixel coordinates; and causing the projector to project a temporal light signal to create a projection of the image on a projection surface, wherein the temporal projector light signal comprises, for each image pixel of the plurality of image pixels, a temporal position information segment encoded with the pixel coordinates of said each image pixel and a color compensation segment configured to reproduce substantially the color of said each image pixel of the plurality of image pixels on the projection surface.

In one or more embodiments, the pixel coordinates are descriptive of a location of the pixel within the image.

In one or more embodiments, the pixel coordinates are descriptive of a location of the pixel within a coordinate system of the projector.

In one or more embodiments, the temporal position information segment is encoded with the pixel coordinates using a sequential binary code comprising a sequential plurality of light pulses.

In one or more embodiments, in the sequential binary code, a first binary digit is represented by a first light pulse followed by a first pause and a second binary digit is represented by a second pause followed by a second light pulse.

In one or more embodiments, the sequential plurality of light pulses of the temporal position information segment are generated using a white color light.

In one or more embodiments, the color compensation segment comprises a sequential plurality of light pulses of a plurality of light colors.

In one or more embodiments, the light pulses in the sequential plurality of light pulses have widths determined based on the color value of the corresponding image pixel.

In one or more embodiments, the sequential plurality of light pulses comprises a red light pulse, a green light pulse and a blue light pulse, wherein the widths of the red light pulse, the green light pulse and the blue light pulse are determined based on the color value of the corresponding image pixel in an RGB color space.

In one or more embodiments, the method additionally involves detecting the temporal light signal using a mobile device positioned within an illumination field of the projector and determining a position of the mobile device based on the temporal position information segment of the detected temporal light signal.

In one or more embodiments, the method additionally involves using the determined position of the mobile device to cause the computerized system or the mobile device to perform a predetermined action.

In accordance with another aspect of the embodiments described herein, there is provided a non-transitory computer-readable medium embodying a set of computer-executable instructions, which, when executed in connection with a computerized system comprising a processing unit, a memory and a projector, cause the computerized system to perform a method involving: receiving an image data, the

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image data comprising at least a color value for each of a plurality of pixels of an image, the color value representing a color of said each of the plurality of image pixels, wherein each of the plurality of image pixels is characterized by pixel coordinates; and causing the projector to project a temporal light signal to create a projection of the image on a projection surface, wherein the temporal projector light signal comprises, for each image pixel of the plurality of image pixels, a temporal position information segment encoded with the pixel coordinates of said each image pixel and a color compensation segment configured to reproduce substantially the color of said each image pixel of the plurality of image pixels on the projection surface.

In one or more embodiments, the temporal position information segment is encoded with the pixel coordinates using a sequential binary code comprising a sequential plurality of light pulses.

In one or more embodiments, in the sequential binary code, a first binary digit is represented by a first light pulse followed by a first pause and a second binary digit is represented by a second pause followed by a second light pulse.

In one or more embodiments, the sequential plurality of light pulses of the temporal position information segment are generated using a white color light.

In one or more embodiments, the color compensation segment comprises a sequential plurality of light pulses of a plurality of light colors.

In one or more embodiments, the light pulses in the sequential plurality of light pulses have widths determined based on the color value of the corresponding image pixel.

In one or more embodiments, the sequential plurality of light pulses comprises a red light pulse, a green light pulse and a blue light pulse, wherein the widths of the red light pulse, the green light pulse and the blue light pulse are determined based on the color value of the corresponding image pixel in an RGB color space.

In accordance with another yet aspect of the embodiments described herein, there is provided a computerized system comprising a processing unit, a projector and a memory storing a set of instructions, the set of instructions including instructions for: receiving an image data, the image data comprising at least a color value for each of a plurality of pixels of an image, the color value representing a color of said each of the plurality of image pixels, wherein each of the plurality of image pixels is characterized by pixel coordinates; and causing the projector to project a temporal light signal to create a projection of the image on a projection surface, wherein the temporal projector light signal comprises, for each image pixel of the plurality of image pixels, a temporal position information segment encoded with the pixel coordinates of said each image pixel and a color compensation segment configured to reproduce substantially the color of said each image pixel of the plurality of image pixels on the projection surface.

In one or more embodiments, the temporal position information segment is encoded with the pixel coordinates using a sequential binary code comprising a sequential plurality of light pulses.

Additional aspects related to the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. Aspects of the invention may be realized and attained by means of the elements and combinations of various elements and aspects particularly pointed out in the following detailed description and the appended claims.

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It is to be understood that both the foregoing and the following descriptions are exemplary and explanatory only and are not intended to limit the claimed invention or application thereof in any manner whatsoever.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification exemplify the embodiments of the present invention and, together with the description, serve to explain and illustrate principles of the inventive technique. Specifically:

FIG. 1 illustrates an exemplary embodiment of a temporal projector light signal in accordance with one or more embodiments described herein.

FIG. 2 illustrates an exemplary embodiment of a digital light processing (DLP) projector using which an embodiment of the described system and method for generating a projected image light signal encoded with position information may be implemented.

FIG. 3 illustrates exemplary embodiments of electrical driving signals applied to the three light sources of a DLP projector as well as the resulting temporal projector light signal encoded with position information.

FIGS. 4(a) and 4(b) illustrate two temporal light signals produced by the digital light processing (DLP) projector, such as the DLP projector, for two different image pixels, in accordance with one or more embodiments of the systems and methods for generating a projected image light signal encoded with position information described herein.

FIG. 5 illustrates an exemplary embodiment of a user-computer interaction system implemented using one or more embodiments of the systems and methods for generating a projected image light signal encoded with position information described herein.

FIG. 6 illustrates an exemplary embodiment of a computerized system for generating a projected image light signal encoded with position information.

#### DETAILED DESCRIPTION

In the following detailed description, reference will be made to the accompanying drawing(s), in which identical functional elements are designated with like numerals. The aforementioned accompanying drawings show by way of illustration, and not by way of limitation, specific embodiments and implementations consistent with principles of the present invention. These implementations are described in sufficient detail to enable those skilled in the art to practice the invention and it is to be understood that other implementations may be utilized and that structural changes and/or substitutions of various elements may be made without departing from the scope and spirit of present invention. The following detailed description is, therefore, not to be construed in a limited sense. Additionally, the various embodiments of the invention as described may be implemented in the form of a software running on a general purpose computer, in the form of a specialized hardware, or combination of software and hardware.

In accordance with one aspect of the embodiments described herein, there is provided a computerized system and a computer-implemented method for generating a projected image signal encoded with position information. In one or more embodiments, the temporal pixel-location data is hidden within the visible light signal used for regular image projection. As would be appreciated by persons of ordinary skill in the art, using the described technique, there

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is no need to modify the light engine of a conventional image projector and there is no need to filter out the visible light at the light receiver side. The embodiments of the described systems and methods enable the user to utilize one or multiple ring-shaped light receivers to implement touch or multi-touch functions on a regular image content generated using the light from the same projector.

In one or more embodiments, the temporal light signal generated by the projector is sliced into multiple temporal segments. In various embodiments, the aforesaid segments include segments of two different types. A segment of the first type is used for carrying a temporal position signal of each pixel in the projector signal. On the other hand, a segment of the second type is used to adjust the color of each pixel. As would be appreciated by persons of ordinary skill in the art, with the color adjustment segment projected to each image pixel, a meaningful visible content of a regular image can be displayed despite the presence of the position-encoded signal segments.

FIG. 1 illustrates an exemplary embodiment of a temporal projector light signal **100** in accordance with one or more embodiments described herein. As shown in FIG. 1, the exemplary temporal projector light signal **100** incorporates a first temporal segment **101** carrying the position information and a second color compensation temporal segment **102**. In other words, in the temporal projector light signal **100** the pixel location information and the regular image projection are time-multiplexed.

In one or more embodiments, the position information is encoded into the position information segment **101** using a sequential binary code. In one embodiment, the aforesaid binary code uses sequence “01” to represent 0 and sequence “10” to represent 1, such that the position information segment **101** will result in a constant luminosity value at every pixel independently of the position information encoded in the segment **101**. In one or more embodiments, the position information segment **101** for each pixel is encoded with two values: a horizontal and vertical position of the pixel within the projector’s illumination field. The encoded coordinates of the pixel may be coordinates in the image coordinate system, the coordinate system of the projector or any other coordinate system. In addition, the image may be segmented into image elements other than the aforesaid image pixels and coordinates of such image elements may be encoded into the position information segments **101**. In one embodiment, position information segments **101** corresponding to pixels within the image element will be identical or at least have the same encoded coordinates.

In one or more embodiments, in addition to the pixel horizontal and vertical coordinates, the position information segment **101** may be encoded with certain additional information, such as identification information (ID) of the system, system time, date, global positioning system (GPS) coordinates of the projector or the system, other location information, such as street address, and the like.

In one or more embodiments, the color compensation segment **102** incorporates sequential color compensation pulses **103**, **104** and **105** for compensating the resulting color of the projected pixel. To this end, the resulting color of the projected pixel is determined by the relative width of the color pulses **103**, **104** and **105** using the pulse-width modulation techniques well known to persons of ordinary skill in the art. Specifically, the wider is the width of a pulse corresponding to a specific color, the more of this color will be present in the resulting projected pixel.

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In one or more embodiments, the color may be encoded using RGB or any other now known or later developed color encoding methodologies. Therefore, the inventive concepts described herein are not limited to any specific color encoding schema. It should be noted that the sequential color pulses **103**, **104** and **105** shown in FIG. 1 correspond to the three primary colors encoding schema, such as the aforesaid RGB technique. On the other hand, if the color encoding uses a different number of primary colors, then the number of the sequential color pulses will be different, matching the number of the primary colors in the color encoding schema.

In one or more embodiments, the widths of the color compensation pulses **103**, **104** and **105** may be proportional to the corresponding color values in the pixel color encoding schema of the image to be projected, such as RGB color encoding well known to persons of ordinary skill in the art. For example, the width of the color compensation pulse **103** of a pixel in a projected image would be proportional to the red color value in the RGB color code for that pixel.

In one or more embodiments, depending on the color image contrast requirements and the position tracking speed requirements, the time duration ratio of the position information segment **101** and the color compensation segment **102** may be adjusted either manually or automatically by the system. In another embodiment, each position information segment **101** may be followed by two, three, four or more color compensation segments **102**, depending on the position tracking speed requirements.

FIG. 2 illustrates an exemplary embodiment of a digital light processing (DLP) projector **200** using which an embodiment of the described system and method for generating a projected image light signal encoded with position information may be implemented. The embodiment of the DLP projector **200** shown in FIG. 2 incorporates three light sources **201**, **203** and **206**, which could be light emitting diodes (LEDs), well known to persons of ordinary skill in the art. In one or more embodiments, the three light sources **201**, **203** and **206** correspond to each of the primary colors, such as red (R), green (G) or blue (B).

The light beams generated by the three light sources **201**, **203** and **206** pass through collection lenses **202**, **204** and **207**, respectively, which direct the light generated by the LEDs **201**, **203** and **206** to the imager. The three resulting light beams are combined together using dichroic mirrors **205** and **208** and the resulting combined light beam passes through the relay lenses **209** and **210** and is directed by a total internal reflection (TIR) prism **211** (a combination of two prisms) onto a digital micromirror device (DMD) **212**. The DMD **212**, which consists of several hundred thousand microscopic mirrors arranged in a rectangular array, selectively reflects the light through the projector lens **213** to generate the resulting image on a remote projection surface (not shown).

It should be noted that the inventive concepts described herein are not limited to LED-based projectors or DLP projectors described above and any other suitable projector systems may be used for implementing the described embodiments.

FIG. 3 illustrates exemplary embodiments of electrical driving signals **301**, **302** and **303** applied to the three light sources **201**, **203** and **206**, respectively, as well as the resulting temporal projector light signal **100** encoded with position information. As shown in FIG. 3, each of the electrical driving signals **301**, **302** and **303** incorporates an identical position information segment (see segment **101** shown in FIG. 1) as well as separate color compensation pulses of varying widths. Combining the light signals pro-

duced by the light sources **201**, **203** and **206** in response to the electrical driving signals **301**, **302** and **303** results in the temporal projector light signal **100**, which is also illustrated in FIG. 1.

FIGS. 4(a) and 4(b) illustrate two temporal light signals produced by the digital light processing (DLP) projector, such as the DLP projector **200**, for two different image pixels, in accordance with one or more embodiments of the systems and methods for generating a projected image light signal encoded with position information described herein. As shown in FIGS. 4(a) and 4(b), a projector **402** creates an image on a projection surface **401**. As shown in FIG. 4(a), a light ray **403** creates an image pixel **404** on the projection surface **401**. Numeral **407** designates a temporal projector light signal **100** corresponding to the image pixel **404**. This temporal projector light signal **100** is encoded with the position information of the image pixel **404** and additionally carries the sequential color compensation pulses described above. On the other hand, as shown in FIG. 4(b), a light ray **405** creates an image pixel **406** on the projection surface **401**. Numeral **408** designates a temporal projector light signal **100** corresponding to the image pixel **406**, which similarly includes the position information of the image pixel **406** as well as the sequential color compensation pulses.

FIG. 5 illustrates an exemplary embodiment of a user-computer interaction system **500** implemented using one or more embodiments of the systems and methods for generating a projected image light signal encoded with position information described herein. In the embodiment shown in FIG. 5, a projector **501** creates an image on a remote projection surface **503** placed within its illumination field **502**. In one or more embodiments, the recreated image may be an image of a graphical user interface. The light emitted by the projector **501** is encoded with the appropriate coordinate information of the corresponding pixel or a group of pixels within the projector illumination field **502**. In one or more embodiments, the coordinate information is encoded in the illumination light of the projector **501** in a form of timed light pulses carrying information of the respective pixel coordinates. In one or more embodiments, the system **500** may include two or more projectors **501** with their illumination fields **502** stitched together or their coded light signals time-multiplexed.

To interact with the displayed user interface or other projected image, the user positions a mobile device **504** in front of the projection surface **503**. The light sensor (not shown) of the so positioned mobile device **504** receives a coded light ray **505** from the projector **501**. In one or more embodiments, the aforesaid light sensor may be the camera unit of the mobile device **504**. In another embodiment, a dedicated luminosity sensor may be used.

In one or more embodiments, the light emitted by the projector **501** is coded with the coordinates of the corresponding pixel within the illumination field of view of the projector **501**. The light sensor of the user's mobile device **504** detects the coded light **505** from the projector **501** and the respective pixel coordinates are extracted from the detected light signal. In one or more embodiments, the coded light **505** may be detected by the conventional camera of the user's mobile device **504** or by a specialized luminosity sensor. In one embodiment, the coordinate information extracted from the detected light signal may be used by the mobile application running on the user's mobile device **504** to request additional information from a server **506**, which corresponds to a portion of the projected image of interest to the user. For example, a video of a geographical

location corresponding to a specific location on a map may be requested by placing the user's mobile device **504** next to the corresponding map point. The mobile device **504** determines the position of a point on the map of interest to the user using the coded lighting and requests the additional information corresponding to the detected map location.

To this end, in one or more embodiments, the mobile device **504** may send a request **508** to the server **506**, the request including the location information for retrieving the associated digital content. In one or more embodiments, the aforesaid request is an HTTP protocol request sent over a computer network.

In response, the server **506** retrieves, based on the location information contained in the received request, the digital associated with the point of interest to the user from a digital content storage **507**. In one or more embodiments, the digital content storage **507** is a database, such as a relational database system of any now known or later developed design. The retrieved digital content **509** is then sent to the user's mobile device **504** via the network. Finally, the software residing on the server **506** may send control signals and/or projected image content **510** to the projector **501**.

In another embodiment, the mobile device **504** transmits the detected coordinate information to the server **506**, which uses this information to detect user's gestures performed in connection with the projected image. The detected gestures, in turn, may be used for enabling user interaction with the server system **506**.

FIG. 6 illustrates an exemplary embodiment of a computerized system **600** for generating a projected image light signal encoded with position information. In one or more embodiments, the computerized system **600** may be implemented within the form factor of a mobile computing device, such as a smartphone, a personal digital assistant (PDA), or a tablet computer, all of which are available commercially and are well known to persons of skill in the art. In an alternative embodiment, the computerized system **600** may be implemented based on a laptop or a notebook computer. Yet in an alternative embodiment, the computerized system **600** may be an embedded system, incorporated into an electronic device with certain specialized functions, such as the DLP projector **200**.

The computerized system **600** may include a data bus **604** or other interconnect or communication mechanism for communicating information across and among various hardware components of the computerized system **600**, and a central processing unit (CPU or simply processor) **601** coupled with the data bus **604** for processing information and performing other computational and control tasks. Computerized system **600** also includes a memory **612**, such as a random access memory (RAM) or other dynamic storage device, coupled to the data bus **604** for storing various information as well as instructions to be executed by the processor **601**. The memory **612** may also include persistent storage devices, such as a magnetic disk, optical disk, solid-state flash memory device or other non-volatile solid-state storage devices.

In one or more embodiments, the memory **612** may also be used for storing temporary variables or other intermediate information during execution of instructions by the processor **601**. Optionally, computerized system **600** may further include a read only memory (ROM or EPROM) **602** or other static storage device coupled to the data bus **604** for storing static information and instructions for the processor **601**, such as firmware necessary for the operation of the com-

puterized system **600**, basic input-output system (BIOS), as well as various configuration parameters of the computerized system **600**.

In one or more embodiments, the computerized system **600** may incorporate a display device **609**, which may be also coupled to the data bus **604**, for displaying various information to a user of the computerized system **600**. In an alternative embodiment, the display device **609** may be associated with a graphics controller and/or graphics processor (not shown). The display device **609** may be implemented as a liquid crystal display (LCD), manufactured, for example, using a thin-film transistor (TFT) technology or an organic light emitting diode (OLED) technology, both of which are well known to persons of ordinary skill in the art. In various embodiments, the display device **609** may be incorporated into the same general enclosure with the remaining components of the computerized system **600**. In an alternative embodiment, the display device **609** may be positioned outside of such enclosure.

In one or more embodiments, the computerized system **600** may incorporate an audio playback device **625** connected to the data bus **604** and configured to play various audio files and streams, such as MPEG-3 files, or audio tracks of various video files, such as MPEG-4 files, well known to persons of ordinary skill in the art. To this end, the computerized system **600** may also incorporate a wave or sound processor or a similar device (not shown). In the described specific embodiments, the audio playback device **625** is configured to play to the user the live audio stream of the video conference.

In one or more embodiments, the computerized system **600** may incorporate one or more input devices, such as a mouse/pointing device **610** for receiving commands from the user, a camera **611** for acquiring still images and video of various objects, as well as a keyboard **606**, which all may be coupled to the aforesaid data bus **604** for communicating information, including, without limitation, images and video, as well as user command selections to the processor **601**.

In one or more embodiments, the computerized system **600** may include a projector **603** for projecting the temporal projector light signal **100** encoded with position information.

In one or more embodiments, the computerized system **600** may additionally include a communication interface, such as a network interface **605** coupled to the data bus **604**. The network interface **605** may be configured to establish a connection between the computerized system **600** and the Internet **624** using at least one of WIFI interface **607** and the cellular network (GSM or CDMA) adaptor **608**. The network interface **605** may be configured to provide a two-way data communication between the computerized system **600** and the Internet **624**. The WIFI interface **607** may operate in compliance with 802.11a, 802.11b, 802.11g and/or 802.11n protocols as well as Bluetooth protocol well known to persons of ordinary skill in the art. In an exemplary implementation, the WIFI interface **607** and the cellular network (GSM or CDMA) adaptor **608** send and receive electrical or electromagnetic signals that carry digital data streams representing various types of information.

In one or more embodiments, the Internet **624** typically provides data communication through one or more sub-networks to other network resources. Thus, the computerized system **600** is capable of accessing a variety of network resources located anywhere on the Internet **624**, such as remote media servers, web servers, other content servers as well as other network data storage resources. In one or more

embodiments, the computerized system **600** is configured send and receive messages, media and other data, including application program code, through a variety of network(s) including Internet **624** by means of the network interface **605**. In the Internet example, when the computerized system **600** acts as a network client, it may request code or data for an application program executing on the computerized system **600**. Similarly, it may send various data or computer code to other network resources.

In one or more embodiments, the functionality described herein is implemented by computerized system **600** in response to processor **601** executing one or more sequences of one or more instructions contained in the memory **612**. Such instructions may be read into the memory **612** from another computer-readable medium. Execution of the sequences of instructions contained in the memory **612** causes the processor **601** to perform the various process steps described herein. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the embodiments of the invention. Thus, embodiments of the invention are not limited to any specific combination of hardware circuitry and software.

The term “computer-readable medium” as used herein refers to any medium that participates in providing instructions to processor **601** for execution. The computer-readable medium is just one example of a machine-readable medium, which may carry instructions for implementing any of the methods and/or techniques described herein. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media.

Common forms of non-transitory computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, or any other magnetic medium, a CD-ROM, any other optical medium, punchcards, paper-tape, any other physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASH-EPROM, a flash drive, a memory card, any other memory chip or cartridge, or any other medium from which a computer can read. Various forms of computer readable media may be involved in carrying one or more sequences of one or more instructions to processor **601** for execution. For example, the instructions may initially be carried on a magnetic disk from a remote computer. Alternatively, a remote computer can load the instructions into its dynamic memory and send the instructions over the Internet **624**. Specifically, the computer instructions may be downloaded into the memory **612** of the computerized system **600** from the foresaid remote computer via the Internet **624** using a variety of network data communication protocols well known in the art.

In one or more embodiments, the memory **612** of the computerized system **600** may store any of the following software programs, applications or modules:

1. Operating system (OS) **613**, which may be an operating system for implementing basic system services and managing various hardware components of the computerized system **600**. Exemplary embodiments of the operating system **613** are well known to persons of skill in the art, and may include any now known or later developed mobile operating systems.

2. Applications **614** may include, for example, a set of software applications executed by the processor **601** of the computerized system **600**, which cause the computerized system **600** to perform certain predetermined functions, such as cause the projector **603** to generate the position-encoded image light signal. In one or more embodiments, the applications **614** may include an inventive user interaction appli-

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cation 615, as well as an inventive projector control application 616, described in detail below.

3. Data storage 619 may be used, for example, for storing the visual content 620.

In one or more embodiments, the inventive user interaction application 615 uses the position information extracted from the temporal projector light signal 100 to detect user gestures and enable user interaction with the computerized system 600 using the detected gestures. On the other hand, the projector control application 616 causes the projector 603 to display the temporal projector light signal 100 described above. In various embodiments, the projector control application 616 may incorporate a position encoding module 617 for encoding pixel coordinates in order to generate the position information segment 101 illustrated above in connection with FIG. 1. In addition, the projector control application 616 may incorporate a color encoding module 618 for encoding pixel color information in order to generate the color compensation segment 102 illustrated above in connection with FIG. 1.

It should be noted that the computerized system 600 described above is exemplary only and any other suitable computerized system may be used to implement the described embodiments.

Finally, it should be understood that processes and techniques described herein are not inherently related to any particular apparatus and may be implemented by any suitable combination of components. Further, various types of general purpose devices may be used in accordance with the teachings described herein. It may also prove advantageous to construct specialized apparatus to perform the method steps described herein. The present invention has been described in relation to particular examples, which are intended in all respects to be illustrative rather than restrictive. Those skilled in the art will appreciate that many different combinations of hardware, software, and firmware will be suitable for practicing the present invention. For example, the described software may be implemented in a wide variety of programming or scripting languages, such as Assembler, C/C++, Objective-C, perl, shell, PHP, Java, as well as any now known or later developed programming or scripting language.

Moreover, other implementations of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. Various aspects and/or components of the described embodiments may be used singly or in any combination in the systems and methods for providing position-encoded image signal using a projector. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

What is claimed is:

1. A computer-implemented method performed in connection with a computerized system comprising a processing unit, a memory and a projector, the computer-implemented method comprising:

- a. receiving an image data, the image data comprising at least a color value for each of a plurality of pixels of an image, the color value representing a color of said each of the plurality of image pixels, wherein each of the plurality of image pixels is characterized by pixel coordinates;
- b. causing the projector to project a temporal light signal to create a projection of the image on a projection surface;

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c. encoding the temporal projector light signal, for each pixel of the projected image, with an information segment comprising the pixel coordinates of the each image pixel of the plurality of image pixels;

d. additionally encoding the temporal projector light signal with a color compensation segment configured to reproduce substantially the color of said each image pixel of the plurality of image pixels on the projection surface, wherein the information segment and the color compensation segment are time-multiplexed within the temporal projector light signal; and

e. detecting the temporal light signal using a mobile device positioned within an illumination field of the projector and determining a position of the mobile device based on the detected temporal light signal, wherein the temporal projector light signal is a visible light signal.

2. The computer-implemented method of claim 1, wherein the pixel coordinates are descriptive of a location of the pixel within the image.

3. The computer-implemented method of claim 1, wherein the pixel coordinates are descriptive of a location of the pixel within a coordinate system of the projector.

4. The computer-implemented method of claim 1, wherein the temporal projector light signal is encoded with the pixel coordinates using a sequential binary code comprising a sequential plurality of light pulses.

5. The computer-implemented method of claim 4, wherein in the sequential binary code, a first binary digit is represented by a first light pulse followed by a first pause and a second binary digit is represented by a second pause followed by a second light pulse.

6. The computer-implemented method of claim 1, wherein the sequential plurality of light pulses of the temporal projector light signal are generated using a white color light.

7. The computer-implemented method of claim 1, wherein the color compensation segment comprises a sequential plurality of light pulses of a plurality of light colors.

8. The computer-implemented method of claim 7, wherein the light pulses in the sequential plurality of light pulses have widths determined based on the color value of the corresponding image pixel.

9. The computer-implemented method of claim 7, wherein the sequential plurality of light pulses comprises a red light pulse, a green light pulse and a blue light pulse, wherein the widths of the red light pulse, the green light pulse and the blue light pulse are determined based on the color value of the corresponding image pixel in an RGB color space.

10. The computer-implemented method of claim 1, further comprising using the determined position of the mobile device to cause the computerized system or the mobile device to perform a predetermined action.

11. A non-transitory computer-readable medium embodying a set of computer-executable instructions, which, when executed in connection with a computerized system comprising a processing unit, a memory and a projector, cause the computerized system to perform a method comprising:

- a. receiving an image data, the image data comprising at least a color value for each of a plurality of pixels of an image, the color value representing a color of said each of the plurality of image pixels, wherein each of the plurality of image pixels is characterized by pixel coordinates;

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- b. causing the projector to project a temporal light signal to create a projection of the image on a projection surface;
- c. encoding the temporal projector light signal, for each pixel of the projected image, with an information segment comprising the pixel coordinates of the each image pixel of the plurality of image pixels;
- d. additionally encoding the temporal projector light signal with a color compensation segment configured to reproduce substantially the color of said each image pixel of the plurality of image pixels on the projection surface, wherein the information segment and the color compensation segment are time-multiplexed within the temporal projector light signal; and
- e. detecting the temporal light signal using a mobile device positioned within an illumination field of the projector and determining a position of the mobile device based on the detected temporal light signal, wherein the temporal projector light signal is a visible light signal.

12. The non-transitory computer-readable medium of claim 11, wherein the temporal projector light signal is encoded with the pixel coordinates using a sequential binary code comprising a sequential plurality of light pulses.

13. The non-transitory computer-readable medium of claim 12, wherein in the sequential binary code, a first binary digit is represented by a first light pulse followed by a first pause and a second binary digit is represented by a second pulse followed by a second light pulse.

14. The non-transitory computer-readable medium of claim 11, wherein the sequential plurality of light pulses of the temporal projector light signal are generated using a white color light.

15. The non-transitory computer-readable medium of claim 11, wherein the color compensation segment comprises a sequential plurality of light pulses of a plurality of light colors.

16. The non-transitory computer-readable medium of claim 15, wherein the light pulses in the sequential plurality of light pulses have widths determined based on the color value of the corresponding image pixel.

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17. The non-transitory computer-readable medium of claim 15, wherein the sequential plurality of light pulses comprises a red light pulse, a green light pulse and a blue light pulse, wherein the widths of the red light pulse, the green light pulse and the blue light pulse are determined based on the color value of the corresponding image pixel in an RGB color space.

18. A computerized system comprising a processing unit, a projector and a memory storing a set of instructions, which, when executed by the processing unit, causes the computerized system to perform a method comprising:

- a. receiving an image data, the image data comprising at least a color value for each of a plurality of pixels of an image, the color value representing a color of said each of the plurality of image pixels, wherein each of the plurality of image pixels is characterized by pixel coordinates;
- b. causing the projector to project a temporal light signal to create a projection of the image on a projection surface;
- c. encoding the temporal projector light signal, for each pixel of the projected image, with an information segment comprising the pixel coordinates of the each image pixel of the plurality of image pixels; and
- d. additionally encoding the temporal projector light signal with a color compensation segment configured to reproduce substantially the color of said each image pixel of the plurality of image pixels on the projection surface, wherein the information segment and the color compensation segment are time-multiplexed within the temporal projector light signal; and
- e. detecting the temporal light signal using a mobile device positioned within an illumination field of the projector and determining a position of the mobile device based on the detected temporal light signal, wherein the temporal projector light signal is a visible light signal.

19. The computerized system of claim 18, wherein the temporal projector light signal is encoded with the pixel coordinates using a sequential binary code comprising a sequential plurality of light pulses.

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